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ABSTRACT

The long term impact of inquiry-based science instruction is explored in this study that examines the relationship between an inquiry-based science program on students' attitudes towards science and interest in science careers several years after participation in the program. The purpose of the study was to evaluate the long term effects of the Summer Science Exploration Program (SSEP) conducted at Hampshire College (Massachusetts) from 1992-1994. Results suggest that a two-week summer science program using an inquiry-based approach may have helped middle school students with a high level of interest in science maintain that level of interest through their years in high school. Teaching methods were shown to also affect student interest and achievement in science. Contains 19 references. (DDR)

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Case Studies of an Inquiry-Based Science Programs' Impact on Students' Attitude Towards Science and Interest in Science Careers

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Abstract

The purpose of this study was to obtain information about the long term impact, if any, of the Summer Science Exploration Program (SSEP), an inquiry-based science camp, conducted at Hampshire College Amherst, MA from 1992 to 1994. The goal of the program was to stimulate greater interest in science and scientific careers among middle school students. One hundred fifty-seven students were randomly selected from a pool of applicants to attend the program. In 1996 twenty-two participants were randomly selected to participate in follow-up interviews. Two quantitative surveys, the Science Opinion Survey and the Career Decision-Making Revised Surveys, were administered to seventy-nine SSEP students and several students who applied but were not accepted. Pre and post scores were analyzed for any significant change. The interviews suggested that SSEP increased students' interest in science. The surveys indicated that, over the years, SSEP students maintained a more positive attitude towards science and a higher interest in science careers than students who applied to the program but were not selected. These findings provide evidence that the program had a positive long-term impact on students' attitude towards science and interest in science careers.

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Introduction

The American Association for the Advancement of Science (AAAS) (1993) and the National Research Council (NRC) (1996) endorse science curricula that actively engage students in science using an inquiry-based approach. This approach has shifted the focus of science education from the traditional memorization of facts and concepts in separate specific disciplines to inquiry-based learning in which students seek answers to their own questions. The pedagogy advocated for is an inquiry approach, in which students are actively engaged using both science processes and critical thinking skills as they search for answers.

The inquiry approach allows students to connect classroom activities with their personal experiences. In contrast, traditional science learning often has little or no connection to students' everyday lives (Papert, 1980). The importance of connecting a problem due to its personal relevance has received attention since Dewey (1938). Learning that is relevant to students' lives motivates them to learn and gives them skills needed to be productive members of society.

Teachers who use the inquiry approach commonly require students to work with others while asking questions and searching for and selecting information to answer their own questions. According to Piaget the "goal of education should be to form minds which can be critical, can verify, and not accept everything offered" (1964, p.5). Inquiry-based learning empowers students to become independent learners.

Many studies conducted in the 70s and 80s found that inquiry-based science activities had positive effects on students' science achievement, cognitive development, laboratory skills, science process skills and understanding of science knowledge as a whole (Mattheis & Nakayama, 1988a;

Padilla, Okey & Garrand, 1984; Purser and Renner, 1983; Saunders and Shepardson, 1984; Schneider and Renner, 1980; Wollman & Lawson, 1978), when compared to students taught using a traditional approach. Additionally, studies have shown that students who use an inquiry approach have improved attitudes towards both science and school while other studies show more negative attitudes resulting from traditional methods (Jaus,1977; Selim & Shrigley, 1983; Shrigley, 1990). Perhaps, as Hodson (1990) suggests, inquiry-based learning is a more effective way for students to learn science, or possibly science learning improves when students' attitudes are positive.

Statement of the Problem

Research on the effectiveness of inquiry-based science programs continues to examine the influence of inquiry-based science on students' performance and science achievement in comparison to traditional science at the end of a treatment period. It appears that studies have not been done which explore the long term impact of inquiry-based science instruction. Given this situation, this study was designed to examine the relationship between an inquiry-based science program on students' attitude towards science and interest in science careers several years after students participated.

Background

The purpose of this study was to evaluate the long term effects of an inquiry-based program, the Summer Science Exploration Program (SSEP), conducted at Hampshire College from 1992-1994. The SSEP was a component of a Science Education Partnership Award (SEPA) Project funded by two agencies of the U. S. Department of Health and Human Services: (1) the Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA), and (2) the

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National Institutes of Health (NIH). The main focus of this study was to obtain information about the impact of the program on students' attitude towards science and interest in science careers.

The Summer Science Exploration Program (SSEP) focused directly on students. This was a summer science camp operated on the Hampshire College campus for students entering grades seven and eight. Over the three year grant period, a two week summer program was offered to 157 middle school students.

The SSEP provided students with the opportunity to explore different biological and health related subjects through inquiry-based learning. Students who participated in this program learned how to formulate their own questions which could be addressed experimentally or through observation. Students designed experiments and practiced laboratory and field techniques that could be used to answer their questions. They also analyzed data through examining their own experiments and those of others. The college science labs provided students with the opportunity to engage in experiences that went beyond what the students experienced in their middle school science classes.

Selected middle school teachers worked together with Hampshire faculty and students to teach in the program. The college faculty brought access to the latest equipment and technology and extensive knowledge and experience in research. The middle school teachers brought highly skilled teaching capabilities and experience dealing with young teenagers. Together they were able to create an air of excitement and a sense of security. The program was designed to excite students' natural curiosity, to provide hands-on laboratory and field experiences, and to give students confidence that "they could do science".

Methodology

Longitudinal Study

The goal of the program was to increase middle school students' interest in science and scientific careers. The focus of this longitudinal study was to determine the extent to which the SSEP's goal had been met and to point to supporting evidence. Through case studies of the experiences of the student participants we gained insights into what worked, what didn't and why. In addition, this study allowed us to share some insights into the potential long term impact of other similar inquiry-based science programs.

In order to investigate the impact of SSEP on students' science attitude and interest in scientific careers, a repeated measurement technique was used. The sample of this study consisted of 79 out of the 157 students who originally participated in the Summer Science Exploration Program (SSEP). Students' pre and post scores were matched on the following two surveys:

1) The Science Opinion Survey produced by the National Association for Educational Progress is a 30 item questionnaire, developed at Florida State University. The Science Opinion Survey assesses current interest and attitudes in science activities at school.

2) Career Decision-Making System Revised (CDM-R) was developed by Thomas F. Harrington and Arthur J. O'Shea (1992). The CDM-R is a comprehensive career interest survey. Students rate their likes and dislikes on 96 questionnaire items that describe career activities.

The pre surveys were administered to students at the beginning of the first day of the program. The post surveys were administered during the Fall of 1996, several years after students participated in the program.

From the pool of 79 SSEP students twenty-two students were randomly selected for interviews after they were sorted by ethnicity and gender. Interviews were conducted with a total of 6 white females, 5 white males, 4 African American females, 2 African American males, 3 Hispanic females, 1 Hispanic male, and 1 Asian American male. The number of students chosen in each category reflected the ethnic and gender makeup of the students who participated in the program. In addition, students who attended camp in each of the years were interviewed. Of the 22 students interviewed six students went to camp in 1992, seven students in 1993, and nine students in 1994.

For comparison purposes thirty-five students who applied to the program but were not accepted completed the post surveys. Fortunately, we discovered that several students in this "control" group had also filled out the pre surveys. This was a very important discovery which will be discussed later.

In addition, in order to study the impact that school science had on students' attitude towards science and interest in science careers, over 500 non-SSEP students, who were in grades 7 through 12, from the public schools the SSEP students attended, were also tested pre and post.

Data Analysis

The extent to which the Summer Science Exploration Program (SSEP) affected students' attitude towards science and interest in scientific careers was determined by triangulation of the data collected by the two methods of evaluation research.

The first method of evaluation was interviews with a selected representative group of students. Qualitative data was collected from the interviews. Topics included in the interviews explored both students' school

and science education experiences. In addition, students were asked to reflect about their experiences at the summer science camp. Students' interests in science and scientific careers were explored, as well as any unexpected issues that emerged during the interviews. Additionally, this analysis considered the possible importance of other external events on students' interest in science and scientific careers. The resulting data from the interviews were coded using HyperRESEARCH (ResearchWare, 1994) a content analysis tool designed for the qualitative researcher. This computer software was used to identify commonalities. This categorization or coding of students' responses provided information for judging how typical a response was.

The second method of evaluation was by surveys administered to all of the SSEP participants who could be located several years after participation in the program, to students who applied to the program but were not accepted, and to a similar group of peers from the same schools. The data from the surveys was compiled and analyzed using Statview, version 4.5. Analyses of Variance (ANOVAs) and t-tests were run to test for statistically statistically significant differences among the groups.

Interview and survey data were compared to provide an understanding of the Summer Science Exploration Program so that generalizations could be made about the effect of participation in the SSEP in changing students' attitudes towards science and interest in scientific careers, as well as identifying the aspects of the program which encouraged those changes.

Quantitative Results

A two sample, t-test found that there was a statistically significant difference ($p < .0001$) between SSEP and non-SSEP students' science attitude

and interest in science careers both in 1992-94 and 1996-97 (Table 1 and 2). This limits the generalizability of the results to other groups, as the SSEP students had different characteristics than other students in the cities selected. This is not surprising as the SSEP students volunteered to take part in the two week summer science camp. In general, it was more likely that students who liked science would apply to attend a science camp than students who did not like science.

Table 1
Students' Science Attitude Mean Scores

Students	# of students	1992-94	1996-97
SSEP	79	.9	.8
control	8	1.4	.5
non-SSEP	>500	.3	-.1

Table 2
Students' Interest in Science Careers Mean Scores

Students	# of students	1992-94	1996-97
SSEP	79	22	19
control	8	22	9
non-SSEP	>500	14	10

Overall, the two survey instruments together found that non-SSEP students had a very low science attitude and were not interested in science careers, and that their average science attitude and interest in science careers decreased slightly from 1992-1994 to 1996-1997 (Table 1 and 2). Similarly SSEP students' attitude towards science and interest in science careers decreased a small amount over the same time period (Table 1 and 2). This small decrease in both groups may perhaps be attributable to the way in which science courses were taught in the schools students attended. In general, it

seems that both SSEP and non-SSEP students lost some interest in science careers as they went from junior high to senior high school.

Because SSEP students were randomly selected from the applicants to participate in the program, it is safe to assume that students who applied but were not accepted had a high interest in science, comparable to the SSEP students. Furthermore, it turned out that the researchers had pre data on eight students out of the thirty-five who applied but were not accepted. The science attitude mean score of these eight students, in 1992-1994, was 1.4, which was above SSEP students' pre mean score of .9 (Table 1 and 2). This finding supports the assumption that the students who applied but were not accepted were comparable to SSEP students.

A two sample t-test found that there was a statistically significant difference in students' post science attitude ($p = .02$) and interest in science ($p < .001$) scores between those who attended camp and those who had applied but were not accepted (Table 1 and 2). The students who attended camp maintained both a higher attitude towards science and a higher interest in science careers than students who applied but were not accepted. Overall, the results clearly indicate that the camp experience had a positive long term impact on students' science attitude and interest in science careers.

Year Students Attended Camp

An ANOVA showed that there was a statistically significant interaction ($p = .02$) between students' science attitude mean scores and the year students attended camp (Table 3). Students who attended camp in 1993 showed a large decrease in science attitude between 1993 and 1997, compared to students who attended camp in 1992 and 1994.

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Table 3
Students' Science Attitude Mean Scores

Year at camp	# of students	1992-94	1996-97
1992	20	.6	.7
1993	29	1.1	.6
1994	25	1.0	1.0

In addition, an ANOVA showed that there was a statistically significant difference ($p = .02$) in SSEP students' interest in science careers pre and post mean scores among the different years students attended camp (Table 4).

Table 4
Students' Science Attitude Mean Scores

Year at camp	# of students	1992-94	1996-97
1992	20	19	20
1993	29	23	18
1994	25	23	20

Students who attended camp in 1993 showed a decrease in interest in science careers from 1992-1994 to 1996-1997. Overall, students who attended camp in 1993, showed a decrease in both their interest in science careers and their attitude toward science, whereas students who went to camp in 1992 and 1994 showed no change in their interest in science careers and their attitude towards science.

What might explain this difference? Was there anything unusual about the summer camp or the group of students during 1993? A possible explanation for the observed decrease in students' attitude towards science in 1993 is related to the design of that year's program. At that time Hampshire

College had for several years been running a summer workshop for the Coalition of Essential Schools. This summer workshop was designed to train teachers in how to use an inquiry-based approach to learning in science classrooms. In 1993, as part of their summer workshop, the Coalition of Essential Schools teachers ran part of the SSEP camp program. This did not turn out well for several reasons. First, the teachers were not experienced working with junior high students. Secondly, the teachers were not experienced using an inquiry-based approach.

Summary of Quantitative Results

Statistical analysis of the results obtained from the two survey instruments revealed the following:

- SSEP students had a more positive attitude towards science and interest in science careers than non-SSEP students.
- Both SSEP and non-SSEP students' attitude towards science and interest in science careers decreased by a small amount as they went from junior high to high school.
- Students who applied but were not accepted to SSEP started off with a high interest in science, like SSEP students, however their interest in science decreased much more than SSEP students' interest in science over the time period studied.
- Students who attended camp in 1993 decreased interest in science by 1996, compared to students who attended camp in 1992 and 1994. This was attributed to the way camp was run that year.

Qualitative Results

Nature and Extent of Impact

Over seventy-five percent of the interviewed students spoke about how SSEP increased their interest in science. It is our assumption that students' interest in science correlates with students' science attitude. Following are a few excerpts from the interviews that demonstrate this point. (To protect students' confidentially each student was assigned a case number.)

Case 12: I enjoyed science more after Hampshire College. It made me more positive towards science. It just made me realize that I wanted to go into the science field. It made me positive that was something that I wanted to do.

Case 16: I think after SSEP I was kind of excited about science. I think I left there admiring it more, the environment of learning, thinking science was fun.

These statements by students are testimony that students increased their interest in science due to their experience at summer science camp. We know that most students who attended camp had a high interest in science to begin with. However, based on these findings we believe that the program may have further enhanced their science attitude.

Aspects of SSEP that Increased Students' Interest in Science

The interview data suggest that students' increased interest in science was related to their enjoyment of the activities they did at camp. Students who attended SSEP had the opportunity to explore science in a fashion that helped

them understand that science could be fun and interesting to do. Seventy percent of the students interviewed mentioned that they really enjoyed the experience. The following excerpts demonstrate what made science at camp enjoyable for students.

Case 5: I remember it was fun. I remember going to a pond once and we got tadpoles and bugs and all that. I liked doing that. Dissecting was good. We dissected a sheep's brain, a sheep's eyeball, and a cow's heart. At first I thought it would be disgusting, but once you actually did it, it wasn't that bad.

Case 10: We would like dissect frogs, we dissected a cow's brain and the heart from a sheep. The teacher was real nice. We watched a lot of videos. It was really fun. I really had fun with science. Teachers made it fun, so it made it enjoyable to learn science. You learned science and it was fun.

From these excerpts it is quite evident that students vividly remembered the dissections. However, it is clear that besides dissections, there were other aspects of the program that made it enjoyable for students, such as: 1) students enjoyed doing hands-on lab activities, 2) the content covered at camp was interesting to students, and 3) the teachers created an enjoyable atmosphere. Overall, the interviews suggest that students' interest in science may have increased because they enjoyed learning science at camp.

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Factors that Make Science Classes Interesting

What makes students interested in science? Most of the students who were interviewed were able to verbalize what would make their current high school science classes more interesting.

Case 2: I like science but I don't like the structured science they give you at school. When I went to the program it was a lot more hands-on touchy freely. I guess in school they just don't have that kind of time. There's a limit.

Case 15: I like science. It's a pretty good subject but it all depends on how you learn it. If a teacher breaks it down for you, if she really goes in-depth in the subject instead of like my teacher now who just gives the notes and expects you to learn everything. At my age, you stop and look and say "Am I ever going to use this in life?" and I think that's a big problem because you gain a negative aspect of the subject.

The interviews showed that students were able to identify some of the key components needed to improve science teaching and learning. Students want less structured science classes with less time devoted to lectures and note taking. Instead, they want the opportunity to do hands-on science activities that are relevant to their lives, the chance to discuss issues, and the time to explore issues in-depth. These components are advocated for by today's educational experts. However, as Nieto (1994) points out, students' perspectives are rarely heard. The point is that students' voices should be heard and taken seriously.

Factors that Impact Students' Interest in Science

According to the students interviewed, the greatest influence on students' attitude and interest appears to be teachers. Over sixty percent of the students spoke about how teachers influenced their attitude. Following are excerpts that demonstrate the impact teachers have on students' attitude.

Case1: Last year my science teacher wasn't good. He just made us read and do questions. If it's just that all the time then it's not interesting. There's not much you can do with that and the teacher wouldn't give you a chance to talk. He would just make us do questions and read. That's it.

Case 6: In chemistry this year we don't get to ask questions, we take notes, read the chapter, do vocab, than take a test. My biology teacher last year loved biology, it was great. I had so many questions, it was so interesting.

Several other important external (to the program) factors that influenced students' science attitude and interest in science careers were uncovered during the interviews. These included parents, the schools students attended, school officials, outreach programs, television, and science clubs.

Aspects of the SSEP that Increased Students' Social Skills

Collaborative learning activities were used to get students to work with one another. The SSEP staff created an environment that fostered and nurtured students. This was apparent from the interviews as several students spoke about the positive atmosphere at camp.

Case 2: When I went there it wasn't that stuff you get taught by a teacher like sit down and be quiet. You get to talk to people, discuss things, explain your ideas, you have an opinion, you speak about it, and you have freedom. Learning is fun if you're in the right environment.

Case 4: I learned to open up more, to let others know what I think. I have always been afraid of participating because I was afraid of getting the wrong answer but I wasn't afraid at Hampshire College. I didn't have to be afraid.

Traditional classrooms often stifle students. In many classrooms students are afraid to speak up for fear that they may give the wrong answer. In addition, some students are afraid of being criticized by their peers. In contrast, the SSEP staff were able to create an environment where students felt safe to voice their opinions and share information with one another. In addition, students at the summer science camp had the opportunity to discuss issues instead of just being lectured to as happens in many classrooms. Furthermore, it is clear that students enjoyed being actively engaged in science discussions.

Summary of Qualitative Results

The interviews revealed the following:

- Seventy-five percent of the students interviewed said that SSEP increased their interest in science.
- Seventy percent of the students interviewed said they really enjoyed the summer science camp experience.

- Students said they would like more hands-on science that is relevant to their lives, the chance to discuss issues, and the time to explore issues in-depth.
- Many factors besides SSEP affected students interest in science (teachers, parents, schools attended, school administrators, after-school programs, television, and science clubs).
- SSEP increased students' social skills.

Conclusion

Changes Over Time

The comparison of non-SSEP students' science attitude data from 1992-1994 with data from 1996-1997 indicated that at both times high school students had a lower interest in science than middle school students. This does not seem surprising when one thinks about the approach to science teaching that is used at the different levels. In general, junior high school science teachers are more apt to use a hands-on inquiry-based approach in helping students learn science than high school teachers. In contrast, many high school science teachers still use traditional methods, lectures and note taking, as a means to teach science to students.

The interviews conducted with SSEP students revealed that some students don't like science when it is taught in a fashion where they are expected to take notes and memorize information. Students said in the interviews that they preferred hands-on inquiry-based science. When science is taught using an inquiry-based approach, students are interested in science. This, in turn, motivates them to put more effort into the subject. The interviews uncovered students' opinions about learning and doing science. We believe that students' perspectives should be listened to and taken seriously.

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The Long-Term Impact of SSEP

The comparison between students who applied but were not accepted, and students who went to camp, indicated that over the years, SSEP students maintained a more positive attitude towards science and a higher interest in science careers. In contrast, students who applied and were not accepted showed a decrease in attitude towards science and interest in science careers over time.

Attending SSEP helped students maintain a high interest in science. Perhaps SSEP acted like a "booster shot". SSEP students started off with a high interest in science, and it appears that the science camp experience helped them maintain that high level of interest.

What is it about the program that might help explain why SSEP students maintained a high interest in science? The pedagogy that was used during summer camp may help explain these findings. Students who participated in SSEP were actively engaged in science using a hands-on inquiry-based approach. The interviews suggest that this is what made science not only enjoyable but also interesting for students. In addition, the interviews with SSEP students indicated that students prefer hands-on inquiry-based science. They stated that this active approach to science is more engaging than sitting and listening to teachers.

Perhaps SSEP reinforced the idea that science can be fun and interesting to do. As stated above, the SSEP students experienced hands-on inquiry-based science. In contrast, the students who applied but were not accepted may have been only exposed to traditional methods of science instruction such as lecturing and note taking.

A possible explanation for the observed decrease in non-SSEP students' interest in science from the time they were in junior high to the time they were in senior high may be the use of traditional methods of science teaching at the high school level. The interviews suggest that students may lose interest in science because of the way their science classes were taught. Some students stated they were "turned off" by learning science through traditional methods which merely included lectures and note taking.

The Long-Term Goal of SSEP

The long-term goal of SSEP was to increase students' interest in science and science careers. The surveys indicated that the program did not, across the board, increase students' interest in science. The original goal may have been unrealistic. At this time, the data suggest that you may not be able to take students with a high initial interest in science and make them more interested in science, because of a ceiling effect.

Summary

This longitudinal study provides evidence that a two week summer science program which used an inquiry-based approach may have helped middle school students with a high level of interest in science maintain a high level of interest in science during their years in high school.

Poor science teaching may cause some students to leave science. In Talking About Leaving: Why Undergraduates Leave the Sciences, Seymour and Hewitt (1997) reported that poor science teaching was the most common complaint (83%) cited by all undergraduate students. They also found that the most effective way to retain students from underrepresented ethnic groups is to improve the quality of the learning experience. It is of extreme importance that

today's science educators focus their attention on the body of knowledge about how people learn. The approach that teachers use to help students learn is an important factor that affects students' interest level. It is apparent from the interviews that students are willing to exert more effort in science classes if they are interested in the material being covered. Traditional methods of instruction may not be as effective as hands-on, inquiry-based methods.

Recommendations for Future Studies

Further research is needed to learn more about what causes students to lose interest in science as they go from junior to senior high school.

Research that compares this program to other inquiry-based programs would be enlightening, regarding factors, circumstances and environments that help students maintain a high interest in science.

Additional studies are needed that follow students for longer periods of time after they participate in inquiry-based science programs. We need to study the impact that inquiry-based programs designed for middle school students have on students' majors in college as well as on their career choices.

The interviews conducted with SSEP students revealed that students felt that teachers greatly influenced their attitude towards science and interest in science careers. Further investigations should be conducted to study the impact of teachers on students' attitude towards science, to discover what specific characteristics are most important.

And lastly, while SSEP (an inquiry-based science program) helped students with a high interest in science maintain that interest over time, further studies should look to see if there is any correlation between students' interest in science and their understanding of science.

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